Pedobiologia 35, 185–190 (1991)
Gustav Fischer Verlag Jena

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A method for studying the morphology of earthworm burrows and their function in respect to water movement

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With 3 figures

(Accepted: 90-10-30)

1. Introduction

The development of the method we want to present was initiated by the question of how earthworm burrows affect water movement. EHLERS (1975) among others studied the effect of earthworm burrows in the field. Since his basic work interest in this scope has increased. Recently a technique was developed to measure percolation in individual burrows in the field (EDWARDS *et al.*, 1989). However, little is known yet about the effects of burrow morphology on the percolating water front. By the method of direct visual observation some questions concerning the interrelationship between soil fabric and water movement may be studied more comprehensively.

In order to study the whole burrow system previous authors like EVANS (1947), BHATTI (1962) and MARTIN (1982) used planar glass cuvettes. The advantage of this technique consists in the reduction of the soil volume to approximately 2 dimensions. Thus it is possible to combine 2 kinds of studies: (1) A morphological study of changes in the soil fabric due to the burrowing activities of the earthworms. (2) A functional study of water movement in relation to burrow morphology. With the application of fluorescent stains it is possible to mark the water front and to follow its movement. A simple and effective percolation equipment in combination with the planar cuvette technique is described.

2. Material and methods

2.1. Planar cuvette technique

2.2. Percolation equipment

The planar cuvettes consisted of 2 glass sheets (14 cm × 14 cm) which were held apart to 0.5 cm by 2 plaster sticks on both sides. Each cuvette was filled with soil aggregates (fraction1 to 2 mm) following ALTEMÜLLER and VORBACH (1987). As soil material we used the Ap horizon of a Parabraunerde from loess (Luvisol). It was moistened before filled into the cuvettes. The maximum possible water content was found to be 17% up to which aggregates did not smear. The bulk density was 1,3 g/cm^3.

Two adult individuals (with clitellum) of *Allolobophora caliginosa* (SAVIGNY, 1826) were placed on the soil surface. After covering the cuvette with laboratory film (Parafilm) the lower part remained open standing in a tub filled with soil. Thus the earthworms could leave the planar cuvettes after burrowing through it. The burrow system and the changes in soil fabric were documented by drawing and photographing from both sides of the cuvette. Usually after 4 days the worms had left the cuvette.

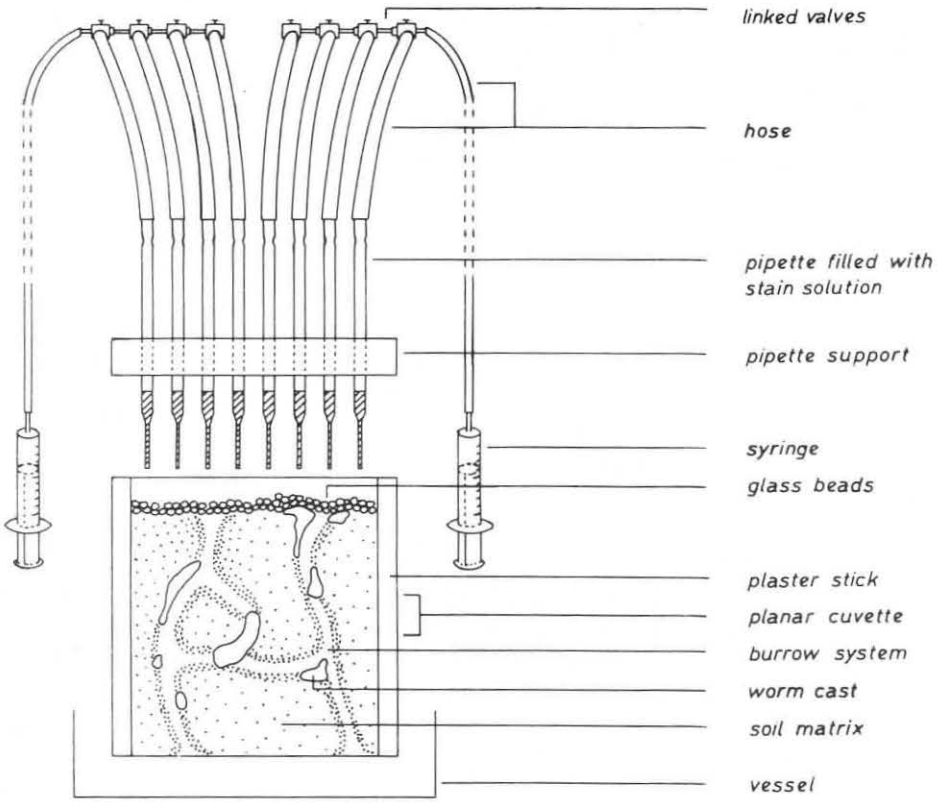

Figure 1. Percolation equipment, schematically.

Figure 1 shows schematically the percolation equipment. With the help of 2 syringes connected with a battery of 8 pipettes a stain solution was applied to the soil surface. The soil surface was covered with a layer of glass beads (4 mm in diameter) in order to protect the surface from slake. Furthermore the glass beads allow a more uniform distribution of the stain solution.

The aqueous stain solution contained the fluorescent dye rhodamine B (C.I. 45170). At a concentration of 1 g l^{-1} downward fingering became obvious. During the course of 1 hour 2 ml of the stain solution were applied 6 times to the soil surface (each pipette contributed 250 µl per application). This amount is equivalent to natural rainfall of about 3.3 to 20 mm h^{-1}. According to BEVEN and GERMANN (1982) intensities of 1 to 10 mm h^{-1} may initiate macropore flow.

After each application the stained percolation front was photographed under UV light with a wavelength of 360 nm (HERAEUS, Fluotest-Forte).

3. Results

3.1. Burrow morphology

The burrowing activity of the earthworms caused various morphological changes of the soil fabric. They can be divided into 5 types as shown in Figure 2 (in order to facilitate a comparison between the 2 sides of the planar cuvette the back side (fig. 2.b) is drawn mirror-inverted).

The burrow system (fig. 2) consists of 3 vertical, somewhat tortuous channels of about 5 mm diameter. In between them the soil fabric remained unchanged. Earthworm casts

were put near the surface and along the burrow system sometimes plugging the channels. Furthermore casts may cover the inside of a channel as it can be seen on the left one (fig. 2.a). In this case the channel remains continuous. The middle one is also continuous and well stabilized mainly by a wall of slightly compacted aggregates. More strongly compacted aggregates generally lost their original shape.

Only by comparing both sides of the cuvette it is possible to find out which part of a channel is continuous and which part is plugged by casts. It is estimated that more than 70% of the burrow system are continuous.

3.2. Percolation experiment

The following experiment showed the passage of the stain solution after each application. The 1st and 2nd application demonstrate that in the unsaturated soil the area directly adjacent to the earthworm channel provides the preferential pathway for the percolating water. Obviously both plugging casts and more strongly compacted walls may function as

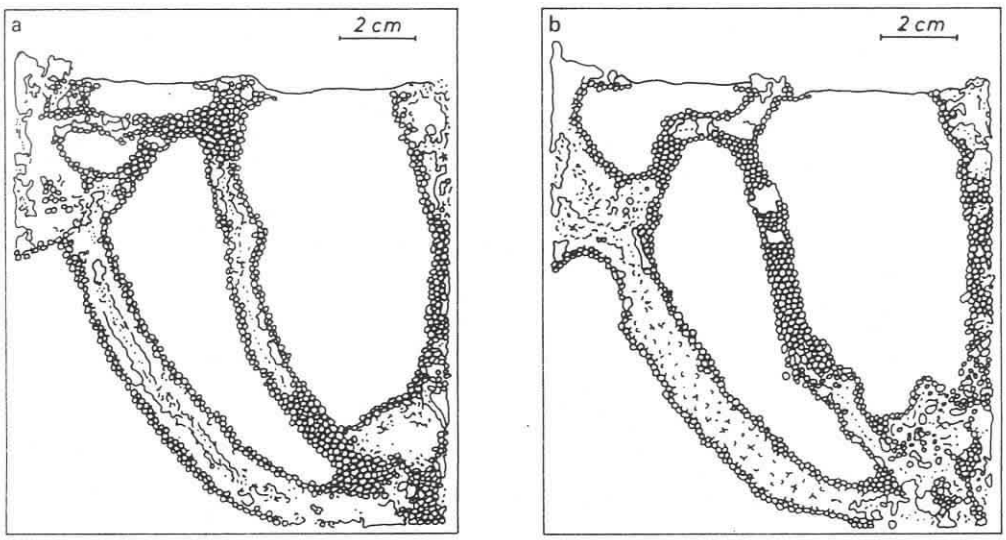

Figure 2. Burrow system of *Allolobophora caliginosa* (SAVIGNY, 1826).
a. Front side.
b. Back side, mirror-inverted.

Unchanged soil fabric.

Earthworm cast.

Slightly compacted aggregates.

More strongly compacted aggregates.

Continuous channel (mucus trace on the glass sheet).

barriers, so that the continuous part in the middle of the left channel became nonconducting (fig. 3). In the lower part of the right hand burrow the water of the 3rd and 4th application was dammed up by more strongly compacted soil. During the 5th and 6th application the stained front became wider and branched out horizontally because field capacity was reached. Comparing the stained water front with the burrow morphology it becomes evident as to why a channel is conducting or nonconducting.

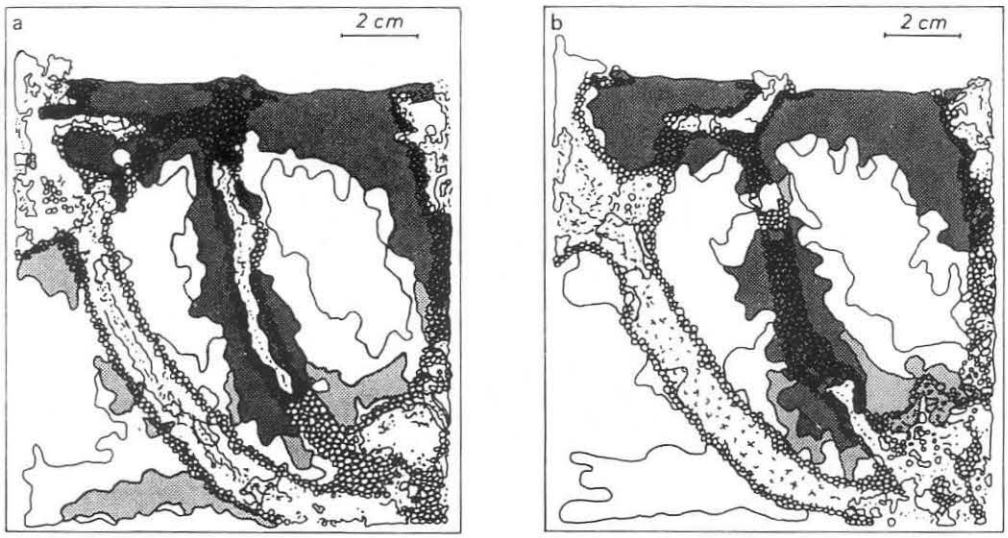

Figure 3. Stained fronts of the percolating water in dependence on the burrow system (rhodamine B: 1 g/l).
a. Front side.
b. Back side, mirror-inverted.

After the 1st and 2nd application: Σ 4 ml.

After the 3rd and 4th application: Σ 8 ml.

After the 5th and 6th application: Σ 12 ml.

4. Discussion

Morphological changes to soil fabric may be studied easily and directly in planar glass cuvettes filled with soil aggregates of defined size fractions. ALTEMÜLLER and VORBACH (1987) introduced this technique when they investigated the effect of root growth on the soil fabric. They adjusted the arrangement of the cuvettes to root growth to get a favourable output. In our study the burrowing of the earthworms caused 5 different morphological features. The slightly compacted soil along the earthworm channels was the preferential pathway of the percolating water. This result is in agreement with the observations of SPEERSCHNEIDER *et al.* (1988). Using a suspended stain (pigmosole-green) they detected preferential flow in the compacted parts of an unsaturated sandy soil.

According to GRAFF (1983) burrowing occurs by the ingestion of soil but mainly by pressing of soil material aside. The interrelationship between the morphological and physical

conditions of the soil has often been neglected. In this study possible effects of the burrow morphology in respect to water movement became visible.

During recent years several stains have been used for studying water movement in soil: e.g. methylene blue (BOUMA & DEKKER, 1978; SMETTEM, 1987), ultramarine blue (EHLERS, 1975), pyranine (OMOTI & WILD, 1979). SMETTEM and TRUDGILL (1983) studied the properties of 2 fluorescent stains: sulpho-rhodamine B and lissamine yellow FF. They are resistant to photochemical decay and exhibit a stable fluorescence over a wide *p*H range (*p*H 3,5 to 10). The choice of a stain must be determined by its adsorption and solubility characteristics. Lack of a staining in the soil does not necessarily imply a lack of water movement (BOUMA & DEKKER, 1978). ALTEMÜLLER (1989) made up the properties of several fluorescent stains and their possible application. He recommends rhodamine B for staining of soil samples because of its low adsorption by clay and high solubility in water.

Fluorescent stains have the advantage of not being much affected by the natural soil colour and mark the stained areas more than diachromes. The use of fluorescent staining together with the cuvette technique provide a direct insight in the nature of water flow in dependence on earthworm burrows.

5. Acknowledgements

We would like to thank Prof. Dr. O. LARINK, Zoological Institute, Technical University Braunschweig, for his support and Prof. Dr. H.-J. ALTEMÜLLER, Institute of Plant Nutrition and Soil Science, FAL Braunschweig, for helpful comments on the manuscript. Also, we are grateful for receiving research funds from the German Research Foundation (Deutsche Forschungsgemeinschaft, DFG, La 226/7-1) which made this study possible. For reviewing the manuscript we thank Mr. R. HICKS.

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Synopsis: *Original scientific paper*

SCHRADER, ST., & M. JOSCHKO, 1991. A method for studying the morphology of earthworm burrows and their function in respect to water movement. Pedobiologia **35**, 185–190.

A method is presented which allows the simultaneous investigation of soil fabric and water movement. Planar glass cuvettes were filled with soil aggregates to study morphological changes of the soil fabric due to the burrowing activity of *Allolobophora caliginosa*. A simple percolation equipment is introduced for applying a defined amount of water to the soil surface. The migrating water fronts were stained by rhodamine B. Under UV light this fluorescent stain showed the preferential pathway of the percolating water in dependence on burrow morphology. This method is of value in observing directly changes in soil fabric and water flow.

Key words: Earthworm burrows, soil fabric, water movement, planar cuvette, percolation equipment, fluorescent staining.

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